Long-term Oceanographic Observations in Western Massachusetts Bay Offshore of Boston, Massachusetts: Data Report for 1989-2000

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U.S. Geological Survey Digital Data Series 74

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DEFINITION OF ABBREVIATIONS USED IN THIS REPORT

Abbreviation	Definition
ADCP	Acoustic Doppler Current Profiler
Argos	Satellite-based location and data collection system developed by Service Argos, Inc.
BASS	Benthic Acoustic Stress Sensor
CECAP	Controlled Environmental Chemical Antifouling Protection
CTD	Conductivity, Temperature, Depth
DLCM	Data Logging Current Meter -- A USGS data logger used on the bottom tripod systems
EPIC	Data storage, retrieval, and management formats and tool maintained by NOAA (see www.pmel.noaa.gov/epic/). Initially began as Equatorial Pacific Information Collection.
LED	Light Emitting Diode
LNB	Large Navigational Buoy
mab	Meters above bottom
mbs	Meters below surface
Matlab	Software marketed by The Math Works, Inc. Natick, MA
MIDAS	Multiparameter Intelligent Data Acquisition System - a USGS data logger used on the bottom tripod systems
MWRA	Massachusetts Water Resources Authority
NDBC	National Data Buoy Center (part of the National Oceanic and Atmospheric Administration)
NetCDF	Network Common Data Form -- A data format and library of data access subroutines maintained by Unidata. See www.unidata.ucar.edu/packages/netcdf
NEWDDISC	A Fortran program used in processing of oceanographic data (outdated)
NOAA	National Oceanic and Atmospheric Administration
NSINP	Non Standard INPut -- Software program developed by WHOI Buoy Group to input data to processing system
PCARPHP	Portable Cassette Reading Program -- Software to convert data recorded on SeaData cassette tapes into a format used by the WHOI Buoy Group
PCMCIA	Personal Computer Memory Card International Association -- A credit card sized memory card for laptop computers
PMEL	Pacific Marine Environmental Laboratory
PSDEV	Pressure Standard DEViation -- Standard deviation of bottom pressure measurements, typically sampled at 1-2 hz. Used as a measure of bottom currents from surface waves
SEACAT	Instrument for time-series measurements of temperature and salinity
SEADAT	A program in C language used to change format of recorded data (outdated)

SeaData	A manufacturer of low-power oceanographic data loggers and tape recorders (no longer in business)
SEASOFT	Software created by Sea-Bird Electronics, Inc. for processing conductivity, temperature, and depth observations
Tattletale	A small, low power computer made by Onset Computer Corporation used in oceanographic data loggers to control sampling and data storage
UCAR	University Corporation for Atmospheric Research
UNESCO	United Nations Educational, Scientific and Cultural Organization
USCG	United States Coast Guard
USGS	United States Geological Survey
VACM	Vector Averaging Current Meter
VAX	A line of mid-range server computers made by Digital Computer Corp. in the 1980's
VMCM	Vector-Measuring Current Meter
VMS	Virtual Memory System -- The operating system for the VAX computer
WHOI	Woods Hole Oceanographic Institution

INTRODUCTION

This data report presents long-term oceanographic observations made in western Massachusetts Bay at 42° 22.6' N., 70° 47.0' W. (Site A, 33 m water depth) from December 1989 through December 2000 (figure 1). This report also presents long-term oceanographic observations made at 42° 9.8' N., 70° 38.4' W. (Site B, 21 m water depth) from October 1997 through December 2000. Site A is approximately 1 km south of the new ocean outfall that began discharging treated sewage effluent from the Boston metropolitan area into Massachusetts Bay on September 6, 2000. These long-term oceanographic observations have been collected by the U.S. Geological Survey (USGS) in partnership with the Massachusetts Water Resources Authority (MWRA) and with logistical support from the U.S. Coast Guard (USCG). The long-term measurements are planned to continue at least through 2002.

The long-term oceanographic observations at Sites A and B are part of a USGS study designed to understand the transport and long-term fate of sediments and associated contaminants in the Massachusetts bays (see http://woodshole.er.usgs.gov/project-pages/bostonharbor/ and Butman and Bothner, 1997). The long-term observations document seasonal and inter-annual changes in currents, hydrography, and suspended-matter concentration in western Massachusetts Bay, and the importance of infrequent catastrophic events, such as major storms or hurricanes, in sediment resuspension and transport. They also provide observations for testing numerical models of circulation.

This data report presents a description of the field program and instrumentation, an overview of the data through summary plots and statistics, and the data in NetCDF, ASCII, and Matlab format for the period December 1989 through December 2000 for Site A and October 1997 through December 2000 for Site B. The objective of this report is to make the data available in digital form and to provide summary plots and statistics to facilitate browsing of the long-term data set.

BACKGROUND

The mean current typically flows southerly through Massachusetts Bay and turns offshore into the Gulf of Maine (figure 2). During much of the year this weak counterclockwise circulation persists in Massachusetts and Cape Cod Bays, principally driven by the southeastward coastal current in the Gulf of Maine. The current proceeds southwesterly into the bay south of Cape Ann, southward along the western shore, and easterly out of the bay north of Race Point, typically at a strength of about 5 cm/s (0.1 knot). Fluctuations of the current caused by wind and density variations alter this simple flow pattern on any day. In most of Massachusetts Bay, the flow-through flushing time for the surface waters ranges from 20 to 45 days.

In western Massachusetts Bay near the outfall site, mixing and transport of water and material into the regional mean flow pattern is accomplished by a variety of processes, including the action of tides, winds, and river inflow. The distance particles travel in a day is typically less than 10 km. The new outfall is located in a region generally to the west of the basinwide residual flow pattern. The residual currents were weak (less than 1 cm/s) at the Site A, and the low-frequency fluctuations were not strongly polarized. In contrast, the mean flow offshore of Scituate (Site B) was stronger, and the low frequency fluctuations generally aligned parallel to the coast. On the basis of this flow pattern, currents observed at Site B were thought to be more representative of the baywide residual circulation pattern, and thus the additional long-term observations at the Site B were initiated in 1997.

Boston Harbor, Stellwagen Basin, and Cape Cod Bay are long-term sinks for fine-grained sediments and associated contaminants. The regional pattern of sedimentary environments in the Boston Harbor/Massachusetts bays sedimentary system is a result of the basin geometry, the supply of sediment, and oceanographic processes. Fine sediments accumulate in the Boston Harbor estuary because of its restricted flushing and low-wave climate. The inner shelf along the western shore of Massachusetts Bay (water depths shallower than 40-50 m) is covered by deposits of gravel, coarse sands, and bedrock. Fine sediments do not accumulate here because storm currents resuspend and remove them from the bottom. The deepest part of the system, Stellwagen Basin, is generally a tranquil environment where fine-grained sediments accumulate.

Strong storms with winds from the northeast resuspend fine sediments from western Massachusetts Bay and transport them offshore and toward Cape Cod Bay. Northeasters, with winds that blow across the Gulf of Maine, generate large waves that enter Massachusetts Bay from the east. The oscillatory currents associated with these waves cause resuspension of the bottom sediments in water depths less than 40 to 50 m over areas exposed to the northeast, principally along the western shore of Massachusetts Bay. Typically only a few millimeters of sediment are resuspended from the seabed during each storm. The currents driven by winds from the northeast flow southeastward parallel to the coast (with an offshore component near the bottom) and carry the suspended sediments toward Cape Cod Bay and offshore into Stellwagen Basin. Sediments settle to the sea floor along this transport pathway following each storm.

Sediments that reach the sea floor in Cape Cod Bay or Stellwagen Basin are likely to remain there. In this coastal system, currents caused by surface waves are the principal cause of sediment resuspension. Cape Cod Bay is sheltered from large waves by Cape Cod, and waves are rarely large enough to resuspend sediments at the seabed in the deep Stellwagen Basin. Thus, once sediments reach Stellwagen Basin or Cape Cod Bay, carried either by the mean flow or transported by storms, it is unlikely that they will be resuspended by waves and transported again.

FIELD PROGRAM

Instruments to measure current, temperature, salinity, bottom pressure, light transmission, suspended matter, and to photograph the sea floor were deployed at Site A from 1989 to 2002. Instruments to measure current, temperature, and suspended matter were deployed at Site B from 1997 to 2002.

In addition to the time-series physical observations, sediment traps were deployed at both Sites A and B. The data they collected are used to estimate the relative amount of suspended sediment falling through the bottom water, to link variations in the trapping rate with changes in oceanographic conditions, and to determine the chemical and physical properties of the trapped sediment. Traps collected samples during storm and non-storm periods and during seasonal cycles in primary productivity, providing information on the nature and amounts of material in transport under different oceanographic conditions. The sample suite was also designed to monitor changes in contaminant concentrations of trapped material since 1989 and especially since the start of the Massachusetts Bay Outfall. Outfall-related changes in chemistry are expected to be detected earlier and more intensively in trapped suspended sediment than in the surficial bottom sediments because trapped sediments are immediately isolated by the sampling device. In contrast, particles falling on the sea floor can be mixed downward by benthic organisms and diluted by older particles from below the water-sediment interface.

Instrumentation was recovered and replaced at each site 3 times each year (typically in February, June, and September). The moorings at Site A and Site B were deployed and recovered using the U.S. Coast Guard Cutter *White Heath* (figure 3A) between 1989 and 1998, and the U.S. Coast Guard Cutter *Marcus Hannah* between 1998 and 2002 (figure 3B). Additional instrument deployments and recoveries in emergencies and gear testing were accomplished using the fishing vessel *Christopher Andrew* (figure 3C).

Site A

The location of the long-term Site A (42° 22.6' N. 70° 47.0' W.) is 13 km east of the entrance to Boston Harbor, at a water depth of about 33 m (figures 1, 4). Because this is an area of heavy marine activity, the instruments were deployed adjacent to the USCG Boston Approach B Buoy to mark the site and to provide some protection from accidental disruption. Instruments were deployed to measure near surface, near bottom, and bottom currents and water properties. During the 13-year period that instruments have been deployed at this site, three configurations of instruments have been used. Deployments of the surface, subsurface, and bottom moorings at Site A were clustered within about a 500-m circle to the south of the USCG buoy B (figure 4). The sea floor at Site A is gravel (figure 5A, B)

1989 - 1994 (figure 6A and 6B)

During this period, the Boston Approach B buoy was a large 40-foot discus buoy capable of supporting oceanographic instrumentation. A vector measuring current meter (VMCM), a transmissometer, and a SEACAT temperature and salinity sensor were suspended at a depth of 5 m below the surface from the Large Navigational Buoy. A second VMCM, transmissometer, and

SEACAT were deployed 10 m above bottom (or about 23 m from the surface) on a taut subsurface current mooring. A bottom tripod system that measured current, temperature, salinity, light transmission, and pressure was deployed on the sea floor. Instruments mounted on the tripod also measured dissolved oxygen, photographed the sea floor, and sampled suspended sediment during selected events. A time series sediment trap at 5 m above bottom (about 28 m from the surface) collected sediments for successive 9-day intervals.

1994 - 1996 (figure 7A and 7B)

In 1994, the 10-m Large Navigation Buoy (LNB) was discontinued and replaced with a smaller buoy that would not support deployment of the near-surface VMCM. A small surface mooring was maintained to allow current measurements 5 m below the surface, and a subsurface mooring was used to obtain measurements at 10 m above the bottom. In addition, Acoustic Doppler Current Profiler (ADCP) measurements were initiated at Site A. The ADCP provided measurements of current from about 6 mab (meters above bottom) to about 5 mbs (meters below surface) in 2-m bins. The ADCP was initially deployed on a small tripod frame (figure 13C) between 1994 and 1996, then on the large tripod frame beginning in 1997.

1997 - 2002 (figure 8A and 8B)

In 1997, the surface mooring was discontinued, and near-surface temperature and salinity measurements were obtained from instruments mounted on the top of the subsurface float about 7 m below the surface. Acoustic Doppler Current Profiler (ADCP) measurements were transferred to the large tripod maintained at Site A. The subsurface mooring collected temperature and conductivity about 7 mbs, measured currents (VMCM), temperature, and conductivity at 10 mab, and held a time-series sediment trap 4 mab.

Time period	Near-surface (5 mbs)	Near-bottom (10 mab)	Bottom (1 mab)	Water Column
1989-1994	VMCM suspended from discus buoy	VMCM, SEACAT	Tripod	
1994-1996	VMCM on surface mooring	VMCM, SEACAT	Tripod	ADCP
1997-2002	Temperature and conductivity on subsurface flotation	VMCM, SEACAT	Tripod	ADCP

Site B

Oceanographic observations were initiated at Site B (42° 9.8' N., 70° 38.4' W., see figure 1 and figure 11A, 11B) in 1997. This location was selected to provide observations along the western shore of Massachusetts Bay in the area of moderate residual flow (figure 2) and storm-driven southeastward flow caused by winds from the northeast (Butman and Bothner, 1997). This location is about 28 km south-southeast from the Massachusetts Bay outfall. Instruments at this site included a bottom-mounted ADCP, time-series sediment trap (4 mab), and near-bottom temperature and conductivity (figure 9A, 9B; figure 10). The ADCP was deployed on several versions of a small tripod frame (figure 13C and 13D).

Deployments of the subsurface and bottom moorings at Site B were clustered within about a 200 m diameter circle (figure 11B). The sea floor at Site B is gravel (figure 12).

SUPPORTING OBSERVATIONS

Meteorological Observations

Wind speed and direction, wave height and period, air temperature, sea surface temperature, and barometric pressure are recorded by instruments maintained in Massachusetts Bay by the National Data Buoy Center (NDBC) at station 44013 (figure 1). Between 1989 and 1993, the meteorological observations were made from the Boston Approach Buoy, a 10-m Large Navigational Buoy (LNB) at Site A. In 1993 the Boston Approach Buoy was replaced with a USCG Horn Buoy. The NDBC station 44013 was moved to a location about 7 km east of Site A (figure 1), and meteorological measurements were made from a 3-m discus buoy. Data from these buoys at 1-hour intervals were obtained from NDBC.

Locations of NDBC Station 44013

Start	End	Platform	Latitude	Longitude
June 1986	September 1990	10-m LNB	42° 23.98 N.	70° 48.00 W.
October 1990	October 1993	10-m LNB	42° 22.80 N.	70° 46.80 W.
November 1993	July 1997	3-m Discus	42° 21.05 N.	70° 41.48 W.
November 1997	Ongoing	3-m Discus	42° 21.23 N.	70° 41.48 W.

Stream Flow Observations

Daily stream flow observations were obtained from the U.S. Geological Survey (http://ma.water.usgs.gov/water_s.htm and http://water.usgs.gov/ma/nwis/discharge). Data from the major river that discharges through Boston Harbor into Massachusetts Bay (the Charles, gaging station 01104500), and from the Merrimack, Parker, and Ipswich Rivers (gaging stations 01100000 , 01101000, and 01102000, respectively), which discharge into the western Gulf of Maine north of Cape Ann, are included in this data report.

INSTRUMENTATION

A variety of sensors from several manufacturers were used to measure current, temperature, conductivity, light transmission, and pressure. Data from these sensors were sampled and recorded by various data logging systems.

Seafloor Tripod Systems (figures 13A, 13B, 13C, and 13D)

USGS seafloor tripod instrument systems measure currents within 1 m of the seafloor; record temperature, pressure, light transmission, and conductivity within 2 m of the seafloor; and photograph the seafloor every few hours. The tripods also hold tube sediment traps. Two versions of the tripod system were used to make the near-bottom observations at Site A. Between 1989 and 1992, a Data Logging Current Meter (DLCM) system was used that measured current with two Savonius rotors and a vane (similar to the VACM current sensor). The DLCM recorded data on a pair of Sea Data tape cassettes or to a hard disk using an Onset Computer Tattletale computer (Butman and Folger, 1979). Between 1991 and 2001, the DLCM was replaced by a MIDAS system that measures current with two BASS 4-axis acoustic current sensors and recorded data using a Tattletale (Martini and Strahle, 1992).

The DLCM tripod system recorded averages of rotor speed and pressure every 7.5 minutes. Measurements of temperature and conductivity were made at the midpoint of the averaging interval. The instrument also burst-sampled current speed, current direction, and pressure every 2 seconds for 72 seconds (180 seconds if recording on a Tattletale) at the center of each 7.5-minute interval. When the DLCM data were processed, the burst current measurements were vector-averaged to obtain current speed and direction, and the standard deviation of the high-frequency pressure measurements, called PSDEV, was computed as a measure of the bottom pressure fluctuations caused by surface waves.

Every second, the MIDAS tripod system recorded pressure and 4 velocity components from each of two BASS acoustic current sensors (Williams, 1985). Every 3.75 minutes, MIDAS computed cumulative sums of pressure and current, and recorded them, along with temperature, conductivity, and light transmission measured at the center of the 3.75-minute averaging interval. Average pressure and current were calculated during postprocessing.

BASS current meters are capable of resolving 0.03 cm/s currents; however, this requires a field determination of the zero. Accuracy is affected by the capacitance of the long cables that connect the data logger to the sensor pods. A new calibration must be obtained each time the data logger and sensor wiring is attached to a tripod frame. An accuracy of 0.3 cm/s can be achieved when the offsets generated by these capacitance changes are measured and removed from the data. The BASS current meter voltages were measured when there was no current through the measurement volume, and this 'zero' offset was subtracted from measurements made during the deployment. A set of experiments were performed to determine the most efficient method of calibrating the BASS to 0.3 cm/s accuracy (Morrison and others, 1993). A zero calibration for the BASS current sensors was obtained with the sensors mounted on the tripod system and connected to the MIDAS data logger prior to deployment and after recovery. A water-tight jacket was fitted around the two BASS sensors, filled with water, and data recorded for at least 12 hours to determine an offset under no-flow conditions.

The MIDAS system measures conductivity using a Seabird SBE-4 conductivity cell, the same design used by Seabird's SEACAT and MicroCAT data loggers described below. On stationary near-bottom platforms such as the tripod, sediment can collect in the conductivity cell and bias the measurement. There is no movement of the instrument system to prevent sediment accumulation. In the middle 1990’s, this was suspected as the cause of a consistent freshening trend seen in the bottom tripod conductivity data. Seabird pumps were added to the MIDAS to flush the conductivity cell prior to making a measurement; and subsequent data sets were no longer affected by this problem.

A 35-mm Benthos camera system was mounted on the tripod frame approximately 2 m above the bottom (figure 13A) and programmed to take a single photograph of the sea floor every 4 hours. The field of view of the downward-looking camera was approximately 1 m by 1.5 m. The photographs are not included in this data report. See Butman and others (1998) for the series of photographs obtained between June and October 1996 (USGS mooring number 470) presented as a time-lapse movie.

Acoustic Doppler Current Profiler (ADCP) (figure 14)

RD Instruments’ ADCP’s (300 Khz Workhorse) were deployed at Site A (beginning in 1994) and Site B (beginning in 1997) to obtain profiles of currents throughout the water column. The instruments measure currents from the doppler shift of sound reflected from the water column from two pairs of orthogonal acoustic beams (figure 14). The instruments recorded 5-minute averages of current every 15 minutes. To obtain an accuracy of at least 0.4 cm/s for each 5-minute measurement, 300 pings emitted at a rate of 1 ping per second were averaged together. A good primer on the doppler current measurement technique may be found in Gordon (1996). At Site A, the ADCP was initially deployed on a small tripod frame (figure 13C) between 1994 and 1996, then on the large frame beginning in 1996. At Site B, the ADCP was deployed on several versions of a small tripod frame (figure 13C and 13D).

Vector-Measuring Current Meter (VMCM) (figure 15)

Vector-measuring current meters (Weller and Davis, 1980) were used to measure temperature and velocity at a sampling interval of 3.75 minutes (figure 15). At the long-term station, VMCM’s were maintained on subsurface moorings at a depth of 10 mab (nominally 23 m). VMCM’s were also suspended from the 40-ft discus buoy, at a depth of 5 m below the surface, from December 1989 until February 1994 when the buoy was discontinued. VMCM’s use orthogonal bidirectional propellers and were configured to sample the currents every 0.25 seconds and vector-average internally to calculate averages at the sampling interval of 3.75 minutes. These samples were recorded on 1/4" cassette tapes by Sea Data recorders.

SEACAT (figure 16)

SEACAT 16 (http://www.seabird.com/) measure conductivity and temperature, and record the voltage signals produced by a transmissometer. SEACAT’s were operated with a sampling interval of 3.75 minutes. SEACAT’s were attached to the VMCM’s that were maintained on subsurface moorings at a depth of 10 mab (nominally 23 m), as well as to the VMCM’s that were suspended below from the 40-ft USCG discus buoy, at a depth of 5 m below the surface, from December 1989 until February 1996. Concern that the SEACAT batteries might be disturbing the VMCM compasses caused a change in mooring design in February 1998, with the SEACAT’s attached to the moorings immediately above the VMCM at a depth of 11 mab.

MicroCAT (figure 17)

The MicroCAT was introduced by Sea-Bird as a lower cost, simpler version of the SEACAT 16. The MicroCAT uses the same sensor technology as the SEACAT to collect salinity and temperature data but cannot record data from additional external sensors such as transmissometers. MicroCAT’s were used to obtain temperature and salinity measurements where turbidity measurements were not needed. The smaller physical size of the MicroCAT enabled these instruments to be installed on the top floats of the subsurface moorings at Site A and Site B. The recording interval was matched to the other instrumentation, typically every 3.75 minutes.

Transmissometer (figure 18)

Sea Tech transmissometers measure the transmission of red light (at a wavelength 650 nm) from a Light Emitting Diode (LED) along a 25-cm water path. The voltage output by a photovoltaic detector was recorded by a SEACAT or by a tripod system. Biological fouling of the transmissometer windows often limited the usefulness of the observations. From October 1992 to October 1994, tests of antifouling rings fitted around transmissometer windows showed some reduction in biological fouling (Strahle and others, 1994). Antifouling rings have been used on all transmissometers since 1994.

Sediment Traps

Time-series sediment traps (figure 10; figure 19)

A time-series sediment trap (model MK 78HW-13) is manufactured by Mclane Research Laboratories, Inc., East Falmouth, Mass. The function and design of the instrument is described by Honjo and others (1988). It consists of a polyethylene funnel 106 cm long with an 80-cm-diameter mouth. The open end of the funnel is fitted with a honeycomb-shaped baffle made of polycarbonate hexagonal cells 3.2 cm in diameter and 7.5 cm long. Covering the baffle is a polyethylene screen (1 cm mesh). The purpose of the baffle and mesh is to reduce turbulence and resuspension in the funnel and to keep out fish and other organisms that are known to take up residence in open traps. Excluding macrofauna from the trap minimizes their direct contribution of excretion products to the sample.

The funnel directs falling particulate matter into one of thirteen 500-ml plastic bottles which are threaded into a rotating plate under the funnel. Each bottle is advanced to the sampling position under the funnel on a selectable schedule assigned using an internal Tattleatale 8 computer. The sampling interval for each bottle is typically about 10 days for a 4-month deployment. Samples are sealed except for the period they are under the funnel. To reduce the decomposition of organic matter in the period between collection and analysis, each bottle is filled with a solution of 5% sodium azide (NaN3) in filtered seawater before deployment. The higher salinity (and density) of the azide solution compared to ambient seawater significantly reduces its diffusion out of the trap during the 4-month collection period.

Although this trap was originally designed for long deployments in the open ocean, the size of the funnel mouth and the bottle volume are appropriate for 4-month deployments at 4.5 m above bottom in this coastal setting (water depth 30 m). Typically, there is a measurable amount of sediment in each bottle, even during quiet periods in summer when resuspension events are infrequent. Occasionally, during an unusually strong storm, the magnitude of sediment resuspension is so great that a sampling bottle overfills and sediments accumulate in and plug the throat of the funnel. Under these conditions the remaining bottles are empty when the trap is recovered. A digital image of the bottles from each deployment was taken in order to visually show the changes in collection rate during the deployment period. This information is not included in this report but is available on request.

Tube sediment traps (figure 10; figure 19)

Traps made simply from standard core tubing were also used on the USGS moorings in order to provide samples at multiple levels in the water column. These traps consist of 60-cm-long polybutyrate tube with a 6.6-cm internal diameter and a wall thickness of 3.2 mm. The bottom of the tube was sealed with a securely taped plastic cap. Baffles consisted of an aramid fiber/phenolic resin honeycomb (trade name: Hexcell) with a cell diameter of 1 cm and a length of 7.5 cm. The material showed no apparent deterioration during exposure to seawater, although it is subject to biofouling. The tube traps are inexpensive to construct and are easily attached to other instruments or to the mooring wire with black electrical tape.

To accommodate different chemical analyses of the trap samples, different preservative solutions were used with little impact on the collection rate. Most traps were filled to within 7.5 cm of the top with a filtered solution of 5% sodium azide in seawater. Some traps at the same location and depth had no preservative, and others were filled with a filtered solution of seawater, 2% buffered formalin with an additional 35 g/kg NaCl. The average standard deviation of trapping rate for the three conditions (azide, formalin, and no poison) was 5% of the mean value. This indicates that the different density gradients in the traps below the Hexcell baffle had little effect on the trapping dynamics of the tube traps.

Trapping efficiency is a factor that must be considered if the results from the tube traps and the time-series traps are compared. A number of studies have discussed the dependence of aspect ratio (height/width), shape, tilt, Reynolds number (UD/k, where U = horizontal fluid velocity, D = trap diameter, and k = kinematic fluid viscosity) and other factors (Butman, 1986; Gardner, 1980, 1986). In this study, a comparison of relative trap efficiency has been determined during a number of field experiments by simply comparing the collection rates in the time-series traps with tube traps fixed at the same location and depth. A summary of the data since 1989 indicates that time-series traps collect at a rate lower than tube traps by a factor of 0.28 +/-0.11. This difference is consistent with a comparison of efficiency between tube traps and funnels up to 50 cm in diameter conducted on the edge of the continental shelf (Bothner and others, 1988).

DATA PROCESSING

Data processing was conducted using the WHOI Buoy Group Data Processing System (Tarbell and others, 1988) and a WHOI-USGS Oceanographic Data Processing System. The Buoy System runs on VAX VMS computers and stores data in a VMS data format. The more recent WHOI-USGS system runs in Matlab (http://www.mathworks.com/) on all computers that have Matlab software and keeps data in EPIC standard NetCDF files (http://www.pmel.noaa.gov/epic/). For compatibility, the older Buoy format data files have been translated to EPIC NetCDF.

In either data processing system, after data were decoded and calibrated, they were carefully checked for instrument malfunctions and then edited. The beginning and end of each data series were truncated and wild points deleted. Short data gaps (less than about 8 data values, which is half an hour for VMCM's and SEACAT's and an hour for tripods) were filled by linear interpolation. The data were carefully checked at each stage of processing. After editing, the basic version of the data file includes all variables recorded at the basic sampling interval. An hour-averaged data file and a low-pass filtered data file were created from the basic version. The low-pass filter essentially removes all fluctuations having periods shorter than 33 hours (Flagg and others, 1976). Low-pass filtered data was subsampled every 6 hours.

Vector-Measuring Current Meter (VMCM)

VMCM's record data on 1/4" cassette tapes using Sea Data recorders. After the VMCMs were recovered, the data were read from the cassette into a file on a personal computer, and then translated into WHOI Carp format, using programs Seadata and PCARPHP (Danforth, 1990). Decoding and calibration were performed using the Buoy Group Data Processing System. Until September 1999, data were edited, truncated, averaged, and filtered using the Buoy System, but since then VMCM data have been written to NetCDF files, and these procedures have been conducted in the WHOI-USGS system.

SEACAT and MicroCAT

SEACAT and MicroCAT data are stored internally. After recovery, SEASOFT programs (Sea-Bird Electronics, Inc.) were used to read the data into a file on a personal computer, convert to calibrated oceanographic units, calculate salinity and density, and write the data to ASCII flat files. ASCII files were translated to Buoy Format or NetCDF, and the data were edited, truncated, averaged, and filtered using the Buoy System (until September 1999) or the WHOI-USGS system.

Acoustic Doppler Current Profiler (ADCP)

The ADCP observations were processed using USGS software (available at http://woodshole.er.usgs.gov/operations/stg/pubs/ADCPtools/) and elements of the WHOI-USGS Oceanographic Data Processing system. The ADCP's were normally configured to record data in beam coordinates (rather than earth coordinates). Upon recovery, the ADCP data were transferred to a personal computer using a PCMCIA flash memory card. These data were converted to NetCDF format using software available for the ADCP Toolbox (above). Matlab routines were used to check for data quality, flag bad values, convert to earth coordinates using a 4-beam or 3-beam solution, truncate the data at the beginning and end of the deployment, and discard bins that were always beyond the water surface. Some near-surface bins were not discarded even though side-beam reflection at times of low tide renders these data invalid, so near-surface ADCP data must be interpreted with care. On occasion, the ADCP skips an ensemble record because the data is poor. Data collected since 2000 have blank placeholders for the missing ensemble records. The end result of processing is an EPIC-compatible data file.

DLCM Tripods

When DLCM data were recorded on Sea Data cassettes, the data were read from the cassette into a file on a personal computer, and then translated into WHOI Carp format, using programs Seadata and PCARPHP (Danforth, 1990). When DLCM data were recorded on a Tattletale hard disk, the Tattletale was attached to a personal computer and the data copied into a file on the computer's hard disk, and then translated into WHOI Carp format using a C language program called SEADAT. Carp format DLCM data from both sources was processed using a Fortran program called NEWDDISC that translates into calibrated oceanographic units and derives current speed and direction, PSDEV, and salinity. The WHOI Buoy Group routine NSINP was then used to translate the data into Buoy Group format, and the data was edited, truncated, averaged, and filtered using the Buoy System.

MIDAS Tripods

MIDAS data were recorded on a Tattletale hard disk and then copied to a personal computer's hard disk after recovery. Until February 1998, a C language program was used to translate the data to calibrated oceanographic units, rotate the velocity to produce east, north, and up components, and calculate pressure standard deviation and velocity variances and covariances from the high-frequency measurements. The result was an ASCII flat file that was translated into the WHOI Buoy Group format using routine NSINP, and the data were edited, truncated, averaged, and filtered using the Buoy System. Since February 1998, the WHOI-USGS system has been used to decode and calibrate the data, compute secondary variables, and perform all further processing.

Initial processing of BASS current meter data is based on the assumption that the speed of sound is constant at 1500 m/s. BASS data from 1991 to 1998 were corrected using a time series of sound speed that was calculated from measured pressure, temperature, and salinity using the UNESCO algorithm (Fofonoff and Millard, 1983). In 1998, it became apparent that the sound speed corrections were smaller than the uncertainty caused by the imprecision of the compass and tilt sensors, so sound speed corrections were discontinued.

Transmissometer

Transmissometer data were processed along with the other data from SEACAT and tripod systems. Beam attenuation coefficients (units of m^{-1}) were computed from the light transmission observations as $-4(\ln(T/100))$, where T is percent light transmission over a beam length of 0.25 m. The beam attenuation coefficient is linearly proportional to the concentration of suspended material in the water if the particles are of uniform size and composition (Moody and others, 1987). However, the size of the particles in the water changes with time, especially during resuspension events, and thus the beam attenuation measurements must be interpreted with care.

Wind Stress

Wind stress was calculated from wind speed and direction using the formulas of Large and Pond (1981). Currents and wind stress were low-pass filtered using the PL33 filter (Flagg and others, 1976), which removes fluctuations having periods shorter than 33 hours. Low-passed data were subsampled every 6 hours.

Sediment Trap Samples

After recovery of the time-series trap, the trap bottles are cleaned and photographed. The contents are then sieved using a 1000-micron polyethylene screen in order to remove filamentous organic matter, such as seaweed, which would complicate the splitting process. Samples are split on a 4-way splitter described by Honjo (1978). The split designated for determination of mass is allowed to settle in a refrigerator for 3-5 days, the overlying clear sea water (and sodium azide) is measured for salinity, siphoned off, and the wet residue is subsequently freeze dried. The mass is corrected for salt content using the weight lost on drying and the measured salinity of the overlying water. The grams collected per m^2 per day are calculated from the measured weight, the time of exposure under the funnel, and the cross sectional area of the trap (0.5 m^2).

BIOLOGICAL FOULING

During the 4-month instrument deployments, the systems were affected by biological and occassionally mechanical fouling. Different organisms of varying densities appeared on surfaces at different depths (figure 20). Biological fouling was typically heaviest on the near-surface instruments and less on the near-bottom instrumentation.

All surfaces of the tripod frames, current sensors, and some instrument cases were painted with antifouling paint (Pettit Marine Paint Trinidad Anti-fouling, Cuprous Oxide 65%, Inerts 35%, EPA reg. #60061-49). In general, this was effective at minimizing fouling over the 4-month deployment, but not always (figures 21A, 21B). The current data files have been truncated when the data begin to be affected by fouling.

The optical windows of the cameras (figure 22) and transmissometers were almost always affected by some biological growth after a 4-month deployment. Beginning in 1991, the windows of the transmissometers were surrounded by a porous plastic ring impregnated, using a vacuum technique, with Controlled Environmental Chemical Antifouling Protection (CECAP, manufactured by Oceanographic Industries) which contains trialkyltin (Strahle and others, 1994). The toxin slowly leached into the water in front of the transmissometer window to retard the growth of barnacles. Between deployments, the ring was cleaned and a new amount of CECAP was impregnated into the material. Although this protection discouraged macrofaunal growth and length of time that good data were obtained (Strahle and others, 1994), accumulation of algal slime on the transmissometer windows continued to gradually blocked light transmission, resulting in a gradual upward drift of the beam attenuation coefficient. ***The beam attenuation data have not been corrected for biological fouling and should be interpreted with care.***

The ports for all of the conductivity cells (on SEACAT's, MicroCAT's, and on the bottom tripod system) were fitted with hollow porous plastic tips impregnated with trialkyltin, to reduce fouling (Oceanographic Industries). Salinities measured by the bottom tripod systems between 1989 and 1996 were erroneously low by as much as 1 psu by the end of the 4-month deployment. ***Salinities have not been corrected for these errors.*** The conductivity cells were apparently affected by a slow, gradual buildup of a biological film on the electrodes and also occasional sudden deposits of material (possibly sediments) inside the measurement volume of the conductivity cell. In June 1996 (mooring 470), Seabird pumps were added to the bottom tripod system to flush the conductivity cell prior to making a measurement, reducing the effect of deposits on the conductivity measurements. The conductivity cells mounted on the subsurface mooring were hypothesized to be less sensitive to the buildup of sediments because of the stronger currents and vibration of the mooring.

Occasionally, the bottom tripod tipped over during the course of a deployment (Tripod mooring 407 tipped over on November 18, 1992, at about 1500 and tripod mooring 428 tipped over on November 16, 1993, at about 1600). When recovered, mooring 407 was entangled with lobster gear (Figure 23). This recovery followed the intense December 1992 storm during which a large amount of lobster gear was lost; it is hypothesized that some of this drifting gear became entangled on the tripod.

MOORING IDENTIFICATION AND MOORING LOG

Every mooring (surface, subsurface, or bottom tripod platform) deployed by the Sediment Transport Group at the USGS Woods Hole Field Center is assigned a 3-digit mooring number that is used to key all information about the mooring and the data. The mooring numbers are assigned in anticipated order of mooring deployment in the field and are roughly sequential, although logistics may alter mooring deployment schedules. An Excel spread sheet mooring log is maintained that summarizes mooring deployments and recoveries. The entries in the mooring log include USGS mooring number, date deployed, date recovered, instrument serial numbers, calibration constants, and other documentation of each mooring and the instrumentation on it. A subset of the electronic mooring log is included in this report for moorings deployed at Site A (referred to as Boston in the location column of the mooring log) and Site B (referred to as Scituate in the location column of the mooring log). For each deployment at Site A and B, the surface and subsurface moorings are assigned one mooring number, and each bottom tripod is assigned a different mooring number. Mooring numbers and data file identifiers are shown on plots of data available.

In addition to the electronic mooring log, paper logbooks are maintained to track instrumentation and field deployments. The Field Mooring Log is the notebook of the field team that physically deploys the instrumentation at sea. The Field Mooring Log includes: USGS mooring number, date and time deployed, date and time recovered, three dimensional spatial location, instrument serial numbers, deployment platform, and descriptions of significant events which occurred during field operations (for example, was a mooring or tripod damaged, were divers necessary for recovery, were sensors fouled). In addition to the Field Mooring Logs, Instrument Logbooks are also kept for each instrument to record upgrades, failures, calibrations and other maintenance actions. These instrument logs are not included in this report.

DATA FILE IDENTIFIERS

The 3-digit mooring number is used to identify all files containing time-series data and is the key through which one can identify and (or) locate data records in the Woods Hole Field Center time-series data management system. Individual data files are labeled by 4-digit numbers: the first three digits being the mooring number, the last digit indicating vertical position of the instrument in the mooring. For example, 5541 identifies the topmost instrument on mooring 554, 5542 the next instrument down on mooring 554, etc. As data files are processed, additional identifiers are added to the four-digit identifier to indicate sensors, processing steps, and averaging (see digital data files).

DATA AVAILABLE

Data included in this report were collected at Site A between December 1989 and December 2000 and at Site B from October 1997 to December 2000. The data include current, temperature, salinity, and beam attenuation at 3 depths (nominally 5 m below surface, 10 m above bottom and 1 m above bottom) and bottom pressure. The instrument turnarounds, typically in February, June, and September, resulted in gaps in the data series a few hours long. Instrument malfunctions, biological or mechanical fouling, deployment delays, and accidental disruption of the instrumentation caused longer gaps in the time-series data. In some instances, an entire 4-month deployment period lacks data. Plots of data coverage have been compiled for the entire project, or by year. For each parameter, the figures shows three lines corresponding to the nominal data sampling depths of 5 mbs, 10 mab, and 1 mab. The USGS mooring number is superimposed on the data line.

STATISTICS OF CURRENT AND TEMPERATURE OBSERVATIONS

Statistics of current and temperature were calculated for the hour-averaged and low-pass filtered measurements, by year and month. The statistics table includes the number of data points used to calculate statistics for the given time period (number). For hour-averaged data, the number is the number of hours of data available in each month. If the number of data points is not equal to 672, 720, or 744 hours for months with 28, 30, or 31 days, respectively, then the data are not complete for that month. For the low-pass filtered data that are subsampled every 6 hours, if the number of data points is not equal to 112, 120, or 124 for months with 28, 30, or 31 days respectively, then the data set is not complete for that particular month. Gaps in the data set are due either to breaks during instrument deployment/retrieval, biological fouling, or instrument malfunctions.

STATISTICS OF METEOROLOGICAL OBSERVATIONS

Statistics of wind stress, air temperature, and sea-surface temperature were calculated for the hour-averaged and low-pass filtered measurements, by year and month. The statistics table includes the number of data points used to calculate statistics for the given time period (number). For hour-averaged data, the number is the number of hours of data available in each month. If the number of data points is not equal to 672, 720, or 744 hours for months with 28, 30, or 31 days, respectively, then the data are not complete for that month. For the low-pass filtered data that are subsampled every 6 hours, if the number of data points is not equal to 112, 120, or 124 for months with 28, 30, or 31 days, respectively, then the data set is not complete for that particular month.

PRINCIPAL AXES OF CURRENTS

Principal axes for both the hour-averaged and low-passed currents were computed by year and month. Major and minor axes, orientation, and ellipticity were computed from the east (u) and north (v) current components as:

major axis = $[0.5\ (UU + VV) + R] / n\}^{1/2}$
minor axis = $[0\ 5\ (UU + VV) - R] / n\}^{1/2}$
orientation = $90° - 0.5 \tan\text{-}1\ [2\ UV / (UU - VV)]$
ellipticity = 1 - (minor axis / major axis)

where

UV = Sum(u*v) - n U V

UU = Sum(u*u) - n U U
VV = Sum(v*v) - n V V
$R = [\ (0.5\ (UU - VV)\ )^2 + UV^2\ ]^{1/2}$

and U and V are the means of the east and north velocity components, respectively. The orientation is measured clockwise from true north. 0 degrees is true north, and 90 degrees is east.

CURRENTS SORTED BY SPEED AND DIRECTION

Hour-averaged and low-passed current observations were sorted into speed and direction bins to provided a measure of the most persistent current speeds and directions. The current measurements are sorted into 88 different bins defined by 2-cm/s speed intervals and 22.5 degree direction intervals. To produce each of tables, the hour-averaged current records of a given depth were sorted into speed/direction bins bounded by the speed values along the left side of the table and the direction values along the top of the table. For example, the upper left bin would contain all currents of speeds less than 2 cm/s flowing toward compass directions between 22.5 and 67.5 degrees, or northeastward. For each bin, the table lists the percentage of the data values that lie within that bin.

TIDAL ANALYSIS

Amplitude and phase of tidal constituents were computed using the tidal analysis program T_TIDE (Pawlowicz and others, in press). The principal constituents are K_1, O_1, M_2, N_2, and S_2.

Summary of principal constituents:

Table headings for pressure:

- Start time: beginning of data record analyzed
- End time: end of data record analyzed
- Amplitude: amplitude of tidal constituent (cm)
- Amp. Error: estimate of error of tidal amplitude (cm)
- Phase: phase of tidal constituent (degrees)
- Phase error: estimate of error in tidal phase (degrees)

Table headings for current:

- Start time: beginning of data record analyzed
- End time: end of data record analyzed
- Major axis: major axis of tidal ellipse (cm/s)
- Maj. Error: error estimate for major axis of tidal ellipse (cm/s)
- Minor axis: minor axis of tidal ellipse (cm/s)
- Min error: error estimate for minor axis of tidal ellipse (cm/s)
- Inclination: inclination of major axis (measured counter clockwise from east (degrees)
- Inc. error: error estimate for inclination (degrees)
- Phase: phase at time of major axis (degrees)
- Phase error: error estimate for phase (degrees)

Site A:

Bottom pressure:
O_1 K_1 M_2 N_2 S_2

Current at 5 mbs (from VMCM):
O_1 K_1 M_2 N_2 S_2

Current at 5 mbs (from ADCP):
O_1 K_1 M_2 N_2 S_2

Current at 10 mab (from VMCM):
O_1 K_1 M_2 N_2 S_2

Current at 15 mbs (from ADCP):
O_1 K_1 M_2 N_2 S_2

Current at 1 mab (from BASS):
O_1 K_1 M_2 N_2 S_2

Current at lowest bin (ADCP):
O_1 K_1 M_2 N_2 S_2

Site B:

Current at 5 mbs (from ADCP):
O_1 K_1 M_2 N_2 S_2

Current at 15 mbs (from ADCP):
O_1 K_1 M_2 N_2 S_2

Current at lowest bin (ADCP):
O_1 K_1 M_2 N_2 S_2

T_Tide analysis for each current meter or bottom pressure record:

Table headings for the T_TIDE analysis output:

- tidal constituent freq: frequency (cycles/hour)
- major: major axis of tidal ellipse (for current observations) (cm/s)
- emaj: error estimate for major axis (cm/s)
- minor: minor axis of tidal ellipse (cm/s)
- emin: error estimate for minor axis (cm/s)
- inc: inclination of major axis (degrees counter clockwise from east)
- einc: error estimate for inclination (degrees)
- phase: phase at time of major axis (degrees)
- ephase: error estimate of phase (degrees)
- snr: signal to noise ratio

+++++ in a column indicates insufficient data to calculate values

Site A:

Pressure/Current (VMCM):

Current (ADCP):

Site B:

Pressure:

Current(ADCP):

TIME SERIES PLOTS OF OCEANOGRAPHIC AND METEOROLOGICAL DATA BY YEAR

Time series plots of selected data from Sites A, B, NOAA Buoy 44013, and from coastal stations are presented by year to provide an overview of the observations. Plots were generated using either hour-averaged data, which show fluctuations with periods of hours, or low-pass filtered data, which show fluctuations with periods of a few days. The low-passed filter is designed to remove fluctuations at tidal periods.

NOAA Buoy 44013

Meteorological Observations at NOAA Buoy 44013: Air temperature (degrees C), barometric pressure (mb), wind speed (m/s), and significant wave height (m) measured at the NOAA buoy 44013

Site A

Coastal river streamflow and salinity and temperature at Site A: Stream flow at Charles, Parker, and Ipswich Rivers (in cubic ft/s), stream flow at the Merrimack River (cubic ft/s), salinity at 5 mbs, 10 mab, and 1 mab (all salinities in psu), and temperature at the surface (NOAA Buoy 44013), 5 mbs, 10 mab, and 1 mab (all temperatures in degrees C). *Salinities in the years 1989 - 1996 may be erronously low due to biological fouling of the sensor* (see biological fouling). Salinities should increase monotonically from the surface to the bottom.

Yearly scatter plots of east and north current for hour-averaged and low-passed current observations at 5 m below surface and 10 m above bottom (VMCM data), and at 1 m above bottom (tripod) at Site A: The hour-averaged scatter plots include all data points. The low-passed scatter plots are subsampled by 6. The principal current ellipse is superimposed. The plots include all data available for the year.

Yearly scatter plots of east and north current for hour-averaged and low-passed ADCP observations at 5 m below surface and from the deepest depth bin available at Site A: The hour-averaged scatter plots include all data points. The low-passed scatter plots are subsampled by 6. The principal current ellipse is superimposed. The plots include all data available for the year.

Monthly mean current and principal current ellipse (calculated from hour-averaged data) at Site A: Monthly observed mean current flow (arrows) and the variability (shown as an ellipse centered around the tip of the mean flow arrow) for current at 5 mbs, 10 mab, and 1 mab. Up is to the north and right is to the east. The mean flow and ellipse were calculated for all months with more than 360 hours of data. Typically the flow originates at the origin of the mean flow arrow and flows toward any point within the current ellipse. The current ellipse calculated from the hour-averaged data is typically dominated by the tidal currents.

Monthly mean current and principal current ellipse (calculated from low-passed data) at Site A: Monthly observed mean current flow (arrows) and the variability (shown as the ellipse centered around the tip of the mean flow arrow) for current at 5 mbs, 10 mab, and 1 mab. Up is to the north and right is to the east. The mean flow and ellipse were calculated for all months with more than 360 hours of data. Typically the current originates at the origin of the mean flow arrow and flows toward any point within the current ellipse. The low-pass filter removes the fluctuating tidal currents, and thus the ellipse reflects variability on time scales of a few days and longer due to wind, density, and forcing from the Gulf of Maine.

Monthly mean current and principal current ellipse (calculated from hour-averaged ADCP data) at Site A: Monthly observed mean current flow (arrows) and the variability (shown as the ellipse centered around the tip of the mean flow arrow) for current at nominally 5 mbs, 15 mbs, and at nearest-bottom observation (all currents in cm/s). Up is to the north and right is to the east. The mean flow and ellipse were calculated for all months with more than 360 hours of data. Typically the current originates at the origin of the mean flow arrow and flows toward any point within the current ellipse. The current ellipse calculated from the hour-averaged data is typically dominated by the tidal currents.

Monthly mean current and principal current ellipse (calculated from low-passed ADCP data) at Site A: Monthly observed mean current flow (arrows) and the variability (shown as the ellipse centered around the tip of the mean flow arrow) for current at nominally 5 mbs, 15 mbs, and at nearest bottom observation (all currents in cm/s). Up is to the north and right is to the east. The mean flow and ellipse were calculated for all months with more than 360 hours of data. Typically the current originates at the origin of the mean flow arrow and flows toward any point within the current ellipse. The low-pass filter removes the fluctuating tidal currents, and thus the ellipse reflects variability on time scales of a few days and longer due to wind, density, and forcing from the Gulf of Maine.

Low-pass filtered wind stress and current observations (from point current meters) at Site A: Low-passed wind stress at NOAA Buoy 44013 (dynes/cm2), low-passed current at 5 m below surface and 10 m above bottom (from Vector Measuring Current Meters), and at 1 m above bottom (from bottom tripod).

Low-pass filtered wind stress and current observations (from profiling current meter) at Site A: Low-passed wind stress (from NOAA Buoy 44013) and low-passed currents at nominally 5 and 15 m below surface and at nearest bottom observation (all currents in cm/s).

Low-pass filtered wind stress and current observations (from profiling current meter) at Site A, all depths: Low-passed wind stress (from NOAA Buoy 44013) and low-passed currents at all depths (all currents in cm/s).

Animation of ADCP data at Site A: The ADCP data can also be viewed using the USGS Velocity Profiler Viewer (VPV), a program that creates an animation of the current at all depths measured by the ADCP in 2 m bins. The VPV data files (with extension .vel) necessary for viewing using VPV are included in this report for each station. In order to view these files, download the free VPV viewer program (vpv.exe). To run VPV, navigate to the .vel file in windows, double click on the .vel file, and choose the vpv.exe program to open. Right click on the animation for help. The noisy uppermost bin of the ADCP time series has been removed from this visualization.

Hourly averaged data: files on this DVD, in directory Data_files/Site_A with filename MB_VPV_file.vel

Low-passed data: files on this DVD, in directory Data_files/Site_A with filename MB_VPV_file_lp.vel

Pressure observations at Site A: Low-passed wind stress (from NOAA Buoy 44013), low-passed bottom pressure (mb), and hour-averaged bottom pressure (mb). The mean has been subtracted from the pressure record prior to plotting.

Surface waves, bottom pressure standard deviation, beam attenuation, bottom current speed, and sediment trapping rate at Site A: Hourly significant wave height (from NOAA Buoy 44013) (m), standard deviation of burst bottom pressure (mb), beam attenuation (m-1), sediment trapping rate (gm/m2/day) at 9-day intervals from Honjo sediment trap, and current speed 1 mab (cm/s). Biological fouling often degrades light transmission data after several months of deployment. Organisms grow on the transmissometer lenses and gradually block light transmission, which results in a gradual upward drift of the beam attenuation coefficient. This drift occurs more quickly and is more severe at shallower depths. *The beam attenuation data plots have not been corrected for biological fouling and should be interpreted with care.*

Low-passed wind stress, surface waves, and beam attenuation at 5 m below surface, 10 m above bottom, and 1 m above bottom at Site A: Low-passed wind stress (dynes/cm^2), hourly significant wave height (from NOAA Buoy 44013) (m), and beam attenuation (m^{-1}) at 5 mbs, 10 mab, and 1 mab. Biological fouling often degrades light transmission data after several months of deployment. Organisms grow on the transmissometer lenses and gradually block light transmission, which results in a gradual upward drift of the beam attenuation coefficient. This drift occurs more quickly and is more severe at shallower depths. *The beam attenuation data plots have not been corrected for biological fouling and should be interpreted with care*.

Trapping rate of tube sediment traps at Site A: Trapping rate of tube traps (gm/m2/day) as a function of height above the sea floor, grouped by recovery date, and for all traps recovered in each year. Traps were recovered 3 times each year, typically in February, June, and September. Symbols differentiate trapping rate for traps with no poison, and those treated with azide or formalin.

Site B

Coastal river streamflow and salinity and temperature at Site B: Stream flow at Charles, Parker, and Ipswich Rivers (in cubic ft/s), stream flow at the Merrimack River (cubic feet/s), salinity at 10-16 mbs and 20-25 mbs (all salinities in psu), and temperature at 10-16 mbs and 20-25 mbs (all temperatures in degrees C). Since data were not consistently available from particular depths, depth ranges were used.

Yearly scatter plots of east and north current for hour-averaged and low-passed ADCP observations at 5 m below surface and from the deepest depth bin available at Site B: The hour-averaged scatter plots include all data. The low-passed scatter plots are subsampled by 6. The principal current ellipse is superimposed. The plots include all data available for the year.

Monthly mean current and principal current ellipse (calculated from hour-averaged ADCP data) at Site B: Monthly observed mean current flow (arrows) and the variability (shown as an ellipse centered around the tip of the mean flow arrow) for current at 4, 10, and 17 m below the surface. Up is to the north and right is to the east. Mean flow and ellipse calculated for all months with more than 360 hours of data. Typically the flow originates at the origin of the mean flow arrow and flows toward any point within the current ellipse. The current ellipse calculated from the hour-averaged data is typically dominated by the tidal currents.

Monthly mean current and principal current ellipse (calculated from low-passed ADCP data) at Site B: Monthly observed mean current flow (arrows) and the variability (shown as the ellipse centered around the tip of the mean flow arrow) for current at 4, 10, and 17 m below the surface. Up is to the north and right is to the east. The mean flow and ellipse were calculated for all months with more than 360 hours of data. Typically the current originates at the origin of the mean flow arrow and flows toward any point within the current ellipse. The low-pass filter removes the fluctuating tidal currents, and thus the ellipse reflects variability on time scales of a few days and longer due to wind, density, and forcing from the Gulf of Maine.

Low-pass filtered wind stress and current observations (from profiling current meter) at Site B: Low pass filtered wind stress (from NOAA Buoy 44013) and low-passed currents at nominally 5 and 15 m below surface and nearest bottom bin.

Animation of ADCP data: The ADCP data can also be viewed using the USGS Velocity Profiler Viewer (VPV), a program that creates an animation of the current at all depths measured by the ADCP. The VPV data files (with extension .vel) necessary for viewing using VPV are included in this report for each station. In order to view these files, download the free VPV viewer program (vpv.exe). To run VPV, navigate to the .vel file in windows, double click on the .vel file, and choose the vpv.exe program to open. Right click on the animation for help. The noisy uppermost bin of the ADCP time series has been removed from this visualization.

Hourly averaged data: files on this DVD, in directory Data_files/Site_B with filename SC_VPV_file.vel

Low-passed data: files on this DVD, in directory Data_files/Site_B with filename SC_VPV_file_lp.vel

Pressure observations at Site B: Low-pass filtered wind stress (from NOAA Buoy 44013), low-passed bottom pressure (mb), and hour-averaged bottom pressure (mb). The mean has been subtracted from the pressure record prior to plotting.

Surface waves, bottom current speed, and sediment trapping rate at Site B: Hourly significant wave height (from NOAA Buoy 44013) (m), near-bottom low-passed current (from nearest bottom ADCP bin (cm/s), sediment trapping rate (gm/m^2/day) at 9-day intervals from Honjo sediment trap, and hour-averaged current speed (from the nearest bottom ADCP bin) (cm/s).

Trapping rate of tube sediment traps at Site B: Trapping rate of tube traps (gm/m^2/day) as a function of height above the sea floor, grouped by recovery date, and for all traps recovered in each year. Traps were recovered 3 times each year, typically in February, June, and September. Symbols differentiate trapping rate for traps with no poison, and those treated with azide or formalin.

Sites A & B

Monthly mean wind stress and principal ellipse, monthly mean current and principal ellipse (calculated from low-passed data at Site A and Site B), and monthly standard deviation of low-passed pressure at Site A: Monthly observed mean current flow (arrows) and the variability (shown as an ellipse centered around the tip of the mean flow arrow) for current at 5 m below the surface at Site A and B. Up is to the north and right is to the east. The mean flow and ellipse were calculated for all months with more than 360 hours of data. Typically the flow originates at the origin of the mean flow arrow and flows toward any point within the current ellipse. The low-pass filter removes the fluctuating tidal currents, and thus the ellipse reflects variability on time scales of a few days and longer due to wind, density, and forcing from the Gulf of Maine.

DIGITAL DATA FILES

Time series oceanographic observations

The time series data from Site A, Site B, and from NOAA Buoy 44013 are included on this DVD-ROM in several formats. For each instrument deployment (see data available or mooring log for mooring numbers), data at the basic sampling interval (typically 3.75 minutes), hour-averaged, and low-passed are included in netCDF format as individual files. Concatenated data (data obtained at common depths merged together) for hour-averaged and low-passed data are included in netCDF, ASCII, and as a Matlab .mat file. ADCP data are included as individual files in netCDF format.

The data format is the EPIC netCDF standard defined by the NOAA Pacific Marine Environmental Laboratory (PMEL). NetCDF is a very general, self-documenting, machine-transportable data format created and supported by UCAR <http://www.unidata.ucar.edu/packages/netcdf/>. EPIC <http://www.pmel.noaa.gov/epic/> is a set of standards which allow researchers from different organizations to share oceanographic data without having to translate "foreign" data types into the local vernacular.

The naming convention for netCDF data files is as follows:

4801Aspd-a1h_d1.cdf

4801A	spd	-a1h	_d1	
			_d1 _d2 etc	(optional) depth identifiers used when a single data logger records the same variables at different depths (requiring separate EPIC "time series" data files)
		-a	best basic version	
		-a1h	hour averaged best basic version	
		-alp	low-pass filtered best basic version	
		-m	merged basic versions	
		-m1l	merged then hour averaged	
	spd or s	velocities corrected for speed of sound		
	v	velocities (averaged or basic time step)		
	tct	temperature, conductivity, transmission		
	p	pressure (averaged or basic time step)		
	psd	pressure standard deviation		
	var	variances and covariances of velocity		
	ox	oxygen		
	cst	conductivity, salinity, temperature		
	t	temperature		
	tc	temperature, conductivity		
	tcp	temperature, conductivity, pressure		
	att or ats	transmission and attenuation		
	pct	pressure, conductivity (salinity), transmission		
	adc	all ADCP variables		
	vm	all VMCM variables		
	sc	all SEACAT variables		
	mc	all MicroCAT variables		
	(none)	all data from this data logger		
Traditional data identifier	First three digits identify moorings chronologically. Fourth digit identifies data loggers sequentially from top. Capital letter suffix (optional) identifies data subsets.			

NOAA Buoy 44013 (wind and waves):

Basic Sampling Interval (NetCDF)
Concatenated Data (NetCDF, Matlab, ASCII)

Site A:

Basic Sampling Interval, Hour-Averaged, and Low-passed Data (NetCDF)
Concatenated Data (NetCDF, Matlab, ASCII)

Site B:

Basic Sampling Interval, Hour-Averaged, and Low-passed Data (NetCDF)
Concatenated Data (NetCDF, Matlab, ASCII)

Sediment Trap Data:

Sediment collection rates for the time-series and tube sediment traps at Sites A and B are presented in an Excel spreadsheet (see definitions of the column headings for an explanation of the columns in this spreadsheet).

Photographs showing sampling bottles from each time-series sediment trap deployment. The heights of the sediment in each bottle provide a visual assessment of the relative collection rate over each 9-day period during the deployment. The measured collection rate in $g/m^2/day$ is plotted in “Time Series Plots”. The list is sorted by date of deployment and the location (either site A or B). Results from a few deployments are missing because the instrument malfunctioned or was lost. Some photographs contain less than the standard 13 bottles or show a nearly full sample bottle followed by a few empty bottles. This pattern occurs when storm resuspension overfills a bottle and plugs the funnel.

Complete Concatenated Data Set:

Also included is a Matlab file contained all of the hourly-averaged concatenated data from Site A, Site B, and NOAA Buoy 44014. This file was created from each of the individual concatenated files references above. In this file, those variables from Site A have been denoted with "A_" in front of the standard variable name, and those from Site B have been denoted with "B_" in front of the standard variable name. Where more than one measurement of a variable is available at different depths from the same site, the depth has been added to the end of the variable name (i.e., whereas the temperature variable is normally T_20, the temperature variable in this file for Site A, 1 mbs is denoted A_T_20_1).

ACKNOWLEDGMENTS

We thank the captains and crews of the U.S. Coast Guard Cutters *White Heath* and *Marcus Hannah* for their outstanding logistical support for this measurement program. The USGS and the USCG safely conducted over 30 cruises to deploy and recover hundreds of individual instruments on over 80 moorings to obtain this long-term data set. Mike Bothner was chief scientist on the USCG cruises. Fran Lightsom oversaw and processed the time-series data. Ben Gutierrez and Soupy Alexander made all of the plots and calculations and assembled the data report. William Strahle and Marinna Martini oversaw the preparation and deployment of the physical oceanographic instrumentation. Bob Barton, Dan Blackwood, Jon Borden, Michael Casso, Jessica Cote, Ray Davis, Peter Gill, Joe Newell, Carol Parmenter, Andre Ramsey, Rick Rendigs, and Richard Signell carried out the work at sea, ashore, and in the laboratory. Rick Rendigs, Dan Blackwood, Larry Ball, Steve Cross, and Ken Parolski aided in the successful recovery of several bottom tripod systems by diving when the primary recovery system failed. Mike Connor, Wendy Leo, Ken Keay, and Mike Mickelson provided encouragement and support from MWRA. Frank Marachi, Captain of the fishing vessel *Christopher Andrew*, provided assistance and valuable local knowledge on a number of cruises. This research was partially supported by a Cooperative Research Agreement between the U.S. Geological Survey and the Massachusetts Water Resources Authority.

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SUPPLEMENTARY FILES

TEXT IN PDF FORMAT

The text of this publication has been included on this CD in PDF format. A PDF including all of the figures with captions is also included.

MATLAB M-FILES

This folder contains m-files that were used to generate the plots and statistics that are published in this report. These files are provided so that users may see examples of how to work with the data files in Matlab. Where NetCDF data are used, users are encouraged to look into the following web page: http://crusty.er.usgs.gov/~cdenham/ and to look into the NetCDF Toolbox which will allow users to work with NetCDF formatted data in Matlab. All of these routines rely on subroutines which may not be readily available. In most cases these subroutines have come from the following sources:

1. http://crusty.er.usgs.gov/~cdenham/snackbar/snackbar.html
2. http://sea-mat.whoi.edu/RPSstuff-html/index.html
3. or the routines have been created by the authors to meet a specific need

In short, we hope that users will be able to use these routines as a guide to deal with the data.

Statistics:

elpspam.m - calculates and outputs ellipse parameters for eastward and northward current components between user specified times on a monthly and yearly basis.

pcaben.m - modified pca.m (Chris Sherwood-USGS) to work with elpspam.m. This routine calculates the ellipse parameters for elpspam.m.

binfix.m - sorts current speed and directions into bins defined by current speed and direction.

binsort.m - called by binfix to do the sorting for binfix.

ltmstat2.m - calculates yearly and monthly statistics for a specified year. Provides statistics of eastward and northward velocities, current speed, and temperature.

stat_driver.m - runs ltmstat2.m.

plotstats.m - plots the statistics results that are output by ltmstat2.m

Time series plots:

ltdatacov2.m - creates horizontal bar plots displaying data coverage over a specified year. Input file is hardwired and consists of data file coverage times.

weathplot.m - plots weather parameters.

rivsal.m - plots river streamflow over a user specified year and then calls tsplot.m to plot temperature and salinity data for the same year. Must get USGS WRD data to run this routine.

tsplot.m - called by rivsal to plot temperature and salinity data for a user specified year.

adcpplot.m - puts together ADCP data files over a specified year to create a four panel plot displaying surface wind stress, and current speed and direction at three depths.

sedtrap.m - plots significant wave height, beam attenuation, sediment trapping rate (estimated with time series sediment trap) and current speed.

honjotrap.m - called by sedtrap to plot sediment trap data.

tubetrap2.m - plots sediment trapping rate measurements that were observed with tube traps.

ALTERNATE VERSION OF SEDIMENT TRAP DATA

The spreadsheet containing the sediment trap data was modified for layout before being included on this CD. Also included here is an alternate version of the spreadsheet (split into Site A and Site B), which was used to create plots of the data. M-files were run on this version of the data.

Site A

Site B